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Growth response and fatty acid composition of juvenile *Penaeus vannamei* fed different sources of dietary lipid

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Abstract

A study was conducted to evaluate the effects of feeding various sources of dietary lipid on weight gain, feed conversion, survival and fatty acid composition of juvenile *Penaeus vannamei*. Seven semi-purified diets (35% protein and 3400 kcal of metabolizable energy kg^{-1}) containing defatted, freeze-dried shrimp meal, 1.0% soybean lecithin and 0.5% cholesterol were supplemented with 6.5% of either stearic acid, coconut, safflower, corn, soybean, linseed or menhaden fish oils. Each diet was fed to shrimp (1.00 ± 0.03 g average weight) in four replicate aquaria four times daily for 10 weeks. Weight gain, feed conversion and survival were best for shrimp fed the diet containing menhaden fish oil. Shrimp fed the linseed oil diet had the second highest weight gain, followed by shrimp on soybean oil, corn oil, stearic acid, coconut oil and safflower oil diets, respectively. Feed conversion values were a reflection of weight gain. Results of this study show that both *n*-6 and *n*-3 fatty acids are dietary essential for juvenile *Penaeus vannamei*, although *n*-3 fatty acids promoted faster growth than *n*-6. However, highly unsaturated fatty acids (HUFA) (20:5*n*-3 and 22:6*n*-3) had better growth-promoting effect than 18:3*n*-3, due probably to the limited ability of shrimp to bioconvert fatty acids to polyenoic forms of longer chain length. The fatty acid composition of the shrimp generally reflected that of the dietary lipids, especially for the diets containing unsaturated fatty acids. Shrimp fed stearic acid and coconut oil diets low in polyunsaturated fatty acids accumulated high levels of 16:1*n*-7 and 18:1*n*-9. Published by Elsevier Science B.V.

Keywords: Shrimp nutrition; *Penaeus vannamei*; Lipids; Fatty acid composition

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1. Introduction

It is generally known that lipids are required in shrimp diets not only as an important source of energy, but also as a source of essential fatty acids (EFA), sterols, phospholipids and fat-soluble vitamins. Several studies have shown that the linoleic (*n*-6) and linolenic (*n*-3) series of fatty acids are dietary essential for *Penaeus aztecus* (Shewbart and Mies, 1973), *Penaeus japonicus* (Kanazawa and Teshima, 1977; Kanazawa et al., 1977a, 1979a; Jones et al., 1979), *Penaeus monodon* and *Penaeus merguiensis* (Kanazawa et al., 1979c), *Penaeus indicus* (Read, 1981), *Penaeus stylirostris* (Fenucci et al., 1981) and *Palaemon serratus* (Martin, 1980). For *Penaeus japonicus*, the nutritional value of linolenic acid was superior to that of linoleic acid (Kanazawa et al., 1977b, 1979d) while eicosapentaenoic or docosahexaenoic acids promoted better growth of *Penaeus japonicus* (Kanazawa et al., 1978, 1979e) and *Penaeus indicus* (Read, 1981) than linolenic acid.

Based on this information, it is reasonable to assume that lipids rich in *n*-6 and *n*-3 highly unsaturated fatty acids (HUFA) such as marine fish oils are better utilized by shrimp. than those low in these fatty acids such as animal fats and vegetable oils. However, results obtained from different feeding studies are contradictory. Beef tallow has been reported to provide better growth and survival of *Penaeus duorarum* than linseed, menhaden and corn oils (Sick and Andrews, 1973). Colvin (1976) observed that the nutritional value of sunflower oil, linseed oil, soybean oil and peanut oil were similar, although it appeared that peanut oil gave the best performance. Vegetable oils high in linolenic acid promoted better growth of *Penaeus japonicus* than those high in linoleic acid, while sardine and short-necked clam oils provided better growth and survival than any of the vegetable oils (Guary et al., 1976). For the same species, Kanazawa et al. (1977a) also reported the superiority of pollack residual oil and short-necked clam oil over soybean oil. *Penaeus monodon* utilized beef tallow and fish oil better than soybean oil, coconut oil, pork lard and corn oil (Mangalik, 1979). However, Catacutan (1991) showed that cod liver oil promoted better growth of *Penaeus monodon* than soybean oil, corn oil, pork lard, beef tallow and coconut oil. Dominy and Lim (1989) reported best growth of *Penaeus vannamei* fed a cod liver oil based diet. Dietary lipids have been found to affect the fatty acid composition of *Penaeus indicus* (Colvin, 1976), *Penaeus japonicus* (Guary et al., 1976; Kanazawa et al., 1977a, 1979d; Deshimaru et al., 1979), *Penaeus setiferus* (Bottino et al., 1980) and *Penaeus monodon* (Catacutan, 1991).

This study was conducted to determine the effects of different sources of dietary lipid on the growth, survival, and whole body proximate and fatty acid composition of juvenile *Penaeus vannamei*.

2. Materials and methods

Seven isonitrogenous and isocaloric diets were prepared to contain 35% protein, 8% lipid and 3400 kcal kg^{-1} metabolizable energy (ME). The composition of the experimental diets was the same except for the lipid source (Table 1). The lipid sources,

Table 1
Percentage composition and estimated nutrient content of basal diet [a]

	% in diet
Ingredient	
Defatted, freeze-dried shrimp muscle	40.0
Dextrin	32.0
Lipid [b]	6.5
Soybean lecithin	1.0
Cholesterol	0.5
Glucosamine–HCl	1.0
Binder [c]	3.5
Vitamin mix [d]	2.0
Mineral mix [e]	7.5
Celufil	6.0
Estimated nutrient content (air dry basis)	
Crude protein (%)	35.0
Crude fat (%)	8.0
ME (kcal kg^{-1} diet)	3300

[a] Butylated hydroxyanisole was added at 0.03% or 300 mg kg^{-1} diet.
[b] Lipid sources were stearic acid, coconut oil, safflower oil, corn oil, soybean oil, linseed oil and menhaden oil.
[c] Mixture of 2.5% kelvis and 1.0% sodium hexametaphosphate.
[c] Supplied the following (mg kg^{-1} diet): vitamin A, 80000 IU; vitamin D_3, 2000 IU; vitamin E, 200; vitamin K, 20; thiamin, 60; riboflavin, 60; pyridoxine, 100; pantothenic acid, 150; niacin, 300; biotin, 2; folic acid, 20; vitamin B_{12}, 0.1; inositol, 300; ascorbic acid, 600; choline chloride, 3000.
[e] Contained the following (g kg^{-1} diet): modified BT_m salt mixture, 25121; $CaHPO_4 \cdot 2H_2O$, 35.80; K_2HPO_4, 16.30; NaCl, 9.0; $MgSO_4$, 0.6; $ZnSO_4 \cdot 7H_20$, 0.17; KI, 0.006; Na_1SeO_3, 0.001; $CoCl_2 \cdot 6H_20$, 0.002.

stearic acid, coconut oil, safflower oil (new variety, relatively rich in oleic acid), corn oil, soybean oil, linseed oil or menhaden oil were added to the basal diet at a level of 6.5%. The protein source was freeze-dried tail muscle of *Penaeus vannamei* extracted with a 2:1 chloroform–methanol mixture in a 1-l Soxhlet device for 3 h. Since the energy values of various feedstuffs are not available for shrimp, the ME values were calculated on physiological fuel values of 4 kcal g^{-1} for protein and carbohydrate and 9 kcal g^{-1} for lipid (Maynard and Loosli, 1969).

The diets were prepared and stored as described by Lim and Dominy (1992) except that drying was done in a Hobart oven at 75°C for 25 min. The fatty acid composition of the experimental diets is given in Table 2.

Juvenile *Penaeus vannamei* obtained from a commercial shrimp farm (Amorient Aquafarm Inc., Kahuku, HI) were acclimated to the laboratory conditions for 2 weeks and fed a commercial feed twice daily. After acclimatization, shrimp with an average initial weight of 1.00 ± 0.03 g were selected and stocked into 28 flowthrough (0.85 l min^{-1}) 60-l glass aquaria at a stocking density of 15 shrimp each. Four aquaria, arranged in the randomized complete-block design, were assigned to each of the experimental diets. Each aquarium, containing 55 l of seawater, was provided with a tight-fitting netting cover, plastic netting shelter and continuous aeration through an air stone. Shrimp which died within 72 h after stocking were replaced by shrimp of similar size.

Table 2
Fatty acid consumption (% by weight of total fatty acids) of experimental diets [a]

Fatty acid	Diet containing:						
	Stearic acid	Coconut oil	Safflower oil	Corn oil	Soybean oil	Linseed oil	Menhaden oil
Saturates							
14:0 and less	–	62.1	–	–	–	–	9.3
16:0	4.8	12.9	7.9	12.8	12.2	8.2	22.6
18:0	84.9	6.2	4.1	3.9	5.1	4.8	5.8
Monoenes							
16:1*n*-7	–	–	–	–	–	–	9.5
18:1*n*-9	2.6	9.2	69.1	23.7	20.2	17.8	9.6
20:1*n*-9	1.6	–	–	–	–	–	0.9
Dienes							
18:2*n*-6	5.2	8.3	17.5	56.2	54.8	20.0	8.7
Trienes							
18:3*n*-3	0.9	1.2	1.0	3.1	7.7	49.1	2.5
Tetraenes							
20:4*n*-6	–	–	–	–	–	–	1.4
Pentaenes							
20:5*n*-3	–	–	–	–	–	–	15.1
Hexaenes							
22:6*n*-3	–	–	–	–	–	–	11.4

[a] Values reported are means of two replicates.

Each test diet was fed to shrimp four times daily to satiation for 10 weeks. Feeds were offered two times in the morning between 10:00 and 11:00 h and two times in the afternoon between 15:00 and 16:00 h. The quantity of feed consumed per aquarium was determined daily.

All aquaria were cleaned daily in the morning by siphoning off accumulated waste materials and exuviae. Before siphoning, prior to each feeding and after sampling, shrimp in all aquaria were checked for mortality. Observed dead shrimp were immediately removed and recorded. Water flow rates were checked and adjusted daily to insure proper water exchange rate. Photoperiod was maintained on a 12:12 h light:dark schedule. Water temperature, salinity, dissolved oxygen and pH were measured in three randomly selected aquaria three times per week. Water temperature ranged from 25.1 to 28.0°C with an average of 26.9 ± 0.8°C; salinity varied from 34.0 to 36.0 ppt and averaged 35.0 ± 0.5 ppt; dissolved oxygen ranged from 5.8 to 6.8 ppm with an average of 6.3 ± 0.2 ppm; pH values ranged from 8.0 to 8.3, average 8.1 ± 0.1.

Every 14 days, the shrimp in each aquarium were counted and weighed en masse. When the shrimp were removed, the aquaria were thoroughly cleaned, drained and refilled. On sampling days, shrimp were fed once in the afternoon with 60% the amount of feed consumed the previous day to minimize cannibalism.

The fatty acid profiles of all diets were determined according to the procedures

described by Tamaru et al. (1992). Samples were freeze-dried and pulverized and lipids were extracted, cleaned, saponified, and methylated. Fatty acid methyl esters were separated and quantified using a HP 5890 gas chromatograph containing a Restek Stabilwax megabore column swept with a temperature gradient of 150–220°C and a 20 cc min^{-1} flow of helium. To each sample, a known quantity of heptadecanoate was added and the recovery rate of the fatty acid determined. Results were adjusted for incomplete recovery of the internal standard.

Approximately 100 shrimp were collected at the start of the experiment and stored at −80°C for determination of whole body proximate and fatty acid composition. At the end of the experiment, all shrimp were collected, pooled according to treatments and stored frozen at −80°C for subsequent chemical analyses. Proximate analyses for moisture, crude protein, crude fat and ash were carried out by a private laboratory using the methods of Association of Official Analytical Chemists (1980). Fatty acid composition was determined following the methods previously described.

All data (except fatty acid profiles) were subjected to analyses of variance and Tukey's test to determine the differences between the treatment means (Steele and Torrie, 1960). Results were considered statistically significant at the 0.05 probability level.

3. Results

The average final weight gain, feed conversion and survival rate of shrimp fed diets containing different lipid sources are presented in Table 3. Shrimp fed menhaden oil diet (diet 7) had the highest weight gain which was significantly higher ($P < 0.05$) than those of shrimp receiving the other diets. The mean weight gain of shrimp fed diet 6 (linseed oil) was the second highest but was not different ($P > 0.05$) from that of shrimp fed 7 the soybean oil diet (diet 5). No significant differences were found among the weight gains of shrimp receiving soybean oil, corn oil and coconut oil (diets 5, 4 and 2, respectively). Shrimp fed safflower oil diet (diet 3) had the lowest weight gain, although

Table 3
Weight gain, feed conversion and survival of shrimp fed various experimental diets [a]

Diet	Weight gain (g)	Feed conversion [b]	Survival (%)
1 (stearic acid)	2.11a	2.55a	53.3ab
2 (coconut oil)	2.04ab	2.31a	45.0a
3 (safflower oil)	1.74a	2.25a	70.7bc
4 (corn oil)	2.34b	1.84ab	63.4abc
5 (soybean oil)	2.60bc	1.70ab	60.0ab
6 (linseed oil)	3.05c	1.78ab	46.7a
7 (menhaden oil)	4.00d	1.18b	81.7c

[a] Values reported are means of four replicates. Means in the same column followed by the same letter are not significantly different at $P > 0.05$.

[b] Feed conversion = Dry feed fed (g)/wet weight gain (g).

not significantly lower ($P > 0.05$) than those of shrimp fed stearic acid and coconut oil diets (diets 1 and 2).

Feed conversion was best for shrimp fed diet 7 (1.18) but was not significantly better ($P > 0.05$) than those obtained with diets 4, 5 and 6 (1.84, 1.70 and 1.78, respectively). Diets 1–3 had feed conversion values ranging from 2.25 to 2.55 but these were not significantly different ($P > 0.05$) from those recorded for diets 4, 5 and 6.

There was a gradual decrease in survival of shrimp fed different experimental diets over the 10-week feeding period. Most of the mortality occurred after week 4 and tended to follow weighing days. However, except for shrimp fed the menhaden oil diet, more extensive mortality occurred after the fourth sampling (week 8). By the end of 10 weeks, shrimp fed diet 2 had the lowest survival (45.0%) although not significantly different ($P > 0.05$) from those of shrimp fed diets 1, 4, 5 and 6 (53.3, 63.4, 60.0 and 46.7%, respectively). Shrimp fed diet 7 had the highest survival (81.7%) but this was not significantly higher ($P > 0.05$) than those fed diets 3 (70.7%) and 4 (63.4%).

Whole body proximate composition of shrimp expressed in percent dry matter is given in Table 4. Moisture content was lowest ($P < 0.05$) for shrimp fed diet 7. Shrimp fed diet 2 had the highest moisture content but this was not significantly different ($P > 0.05$) from that on diet 5. Crude protein content differed significantly ($P < 0.05$) among shrimp receiving various dietary treatments and ranged from 76.64 to 78.73%. However, except for the protein content of shrimp fed diet 4, the values obtained with other treatments varied only between 78.10 and 78.73%. Percentages of crude fat appear to be related to the weight gains. Fat contents of shrimp fed diets 1 and 2 were similar and were significantly lower ($P < 0.05$) than those of shrimp fed the other diets. Shrimp fed diet 7 had the highest body fat content. For ash content, the trend seems to be the reverse of that of body fat.

The fatty acid patterns of total lipid of shrimp (Table 5) were influenced by the fatty acid composition of the diets. Shrimp fed menhaden oil diet had fatty acid profile similar to that of initial shrimp and contained high levels 20:5*n*-3 and 22:6*n*-3. The percentages of these fatty acids decreased in shrimp fed the other diets. Shrimp fed linseed oil diet had a high level of 18:3*n*-3, while those fed safflower oil diet had a high level of 18:1*n*-9. The percentages of 18:2*n*-6 were high for shrimp fed corn and soybean oil diets. However, shrimp fed stearic acid and coconut oil diets had lower saturated fatty

Table 4
Whole body proximate composition (% dry matter basis) of shrimp fed various experimental diets [a]

Diet	Moisture	Protein	Fat	Ash
1 (stearic acid)	76.22bc	78.73d	3.11a	14.60e
2 (coconut oil)	77.77d	78.25bc	3.13a	14.74f
3 (safflower oil)	76.74bc	78.93e	3.30b	14.20d
4 (corn oil)	76.41b	76.24a	3.71d	14.69ef
5 (soybean oil)	77.36ca	78.30e	3.63c	13.45c
6 (linseed oil)	76.01b	78.64d	3.83c	12.73b
7 (menhaden oil)	74.84a	78.10b	4.45f	12.02a

[a] Values reported are means of three replicates. Means in the same column followed by the same letter are not significantly different at $P > 0.05$.

Table 5
Whole body fatty acid composition (% by weight of total fatty acids) of shrimp before and after the feeding trial [a]

Fatty acid	Initial	Shrimp fed diet containing:						
	acid	Stearic oil	Coconut oil	Safflower oil	Corn oil	Soybean oil	Linseed fish oil	Menhaden
Saturates								
14:0	2.0	0.8	2.4	0.7	0.6	0.3	0.6	1.6
16:0	24.0	17.6	19.2	15.6	17.3	16.7	15.8	23.0
18:0	9.9	11.7	9.6	7.3	9.9	10.6	10.6	11.5
Monoenes								
16:1*n*-7	2.7	4.2	4.0	1.0	0.6	0.6	0.6	3.3
18:1*n*-9	14.6	23.8	20.8	38.8	17.9	15.7	17.0	12.5
20:1*n*-9	1.0	0.8	0.8	1.0	0.6	0.6	0.6	1.0
Dienes								
18:2*n*-6	10.9	15.5	15.6	15.9	35.8	35.9	17.6	9.2
Trienes								
18:3*n*-3	1.2	1.7	1.6	1.0	1.6	4.2	23.3	1.3
Tetraenes								
20:4*n*-6	3.0	3.4	3.6	2.8	2.2	2.2	2.1	2.6
Pentaenes								
20:5*n*-3	16.6	12.1	12.8	9.7	8.0	7.4	7.0	20.7
Hexaenes								
22:6*n*-3	13.6	8.4	9.2	6.9	6.1	5.5	5.2	13.1

[a] Values reported are means of three replicates.

acid contents than those of the initial and menhaden oil fed shrimp but accumulated high levels of monoenes (16:1*n*-7 and 18:1*n*-9).

4. Discussion

Based on the growth performance, menhaden oil was better utilized by juvenile *Penaeus vannamei* than linseed, soybean, corn, safflower, and coconut oils, and stearic acid. Previous studies have also reported the superior nutritional value of marine oils such as sardine, pollack, short-necked clam and cod liver oils over plant oils or animal fats for *Penaeus japonicus, Penaeus monodon* and *Penaeus vannamei* (Guary et al., 1976; Kanazawa et al., 1977a; Dominy and Lim, 1989; Catacutan, 1991). Among plant oils, oil rich in 18:3*n*-3 fatty acid (linseed oil) promoted better growth of *Penaeus vannamei* than oils rich in 18:2*n*-6 (soybean and corn oils), whereas those containing high levels of 18:1*n*-9 (safflower oil) or saturated fatty acids (coconut oil and stearic acid) performed very poorly. A similar observation was made by Guary et al. (1976) for *Penaeus japonicus*. This suggests that 18:3*n*-3 had better nutritional value for *Penaeus vannamei* than 18:2*n*-6 as has been reported by Kanazawa et al. (1977b) for *Penaeus*

japonicus. Thus, *Penaeus vannamei* appear to have a dietary requirement for linoleic and linolenic series of fatty acids as have been reported for *Penaeus aztecus* (Shewbart and Mies, 1973), *Penaeus japonicus* (Kanazawa and Teshima, 1977; Kanazawa et al., 1977b, 1979a,d; Jones et al., 1979), *Penaeus monodon* and *Penaeus merguiensis* (Kanazawa et al., 1979c), *Penaeus indicus* (Read, 1981), *Penaeus stylirostris* (Fenucci et al., 1981) and *Palaemon serratus* (Martin, 1980). The better growth-promoting effect of menhaden oil obtained in the present studies may be due to the presence of HUFA, especially 20:5*n*-3 and 22:6*n*-3 which have better nutritional value that of 18:3*n*-3. Previous studies have shown that 20:5*n*-3 or 22:6*n*-3 provided better growth of *Penaeus japonicus* (Kanazawa et al., 1978, 1979e) and *Penaeus indicus* (Read, 1981).

Although both *n*-3 and *n*-6 fatty acids appeared to be essential for the growth of *Penaeus vannamei*, *n*-3 HUFA were required for maximum survival. Stress due to handling was the major cause of mortality observed in the current study. Guary et al. (1976) found that diets containing marine oils from sardine or clam which are high in 20 and 22 carbon *n*-3 fatty acids promoted better survival of *Penaeus japonicus* than any of the vegetable oil diets. The survival of *Penaeus japonicus* fed a soybean oil diet was extremely low compared with those of shrimp fed diets containing pollack residual oil or shortnecked clam oil (Kanazawa et al., 1977a). Kanazawa et al. (1977b) reported that supplementation of linoleic or linolenic acids to the diet containing oleic acid greatly improved the survival of *Penaeus japonicus* but this was still considerably less than that of shrimp fed the pollack residual oil diet. With *Penaeus indicus*, Read (1981) obtained a further improvement in the survival when linoleic and linolenic acids were included with anchovy oil.

Whole body protein did not seem to be related to the types of dietary lipid, although there were some statistical differences. Carcass lipid, however, tended to be affected by the nutritional value of dietary lipid with shrimp fed the menhaden oil diet had the highest fat content. Likewise, Catacutan (1991) observed an increased level of carcass lipid of *Penaeus monodon* fed a diet containing cod liver oil. Colvin (1976) indicated that the more unsaturated nature of marine oils as compared with that of plant oils may have had an influence on fat deposition in *Penaeus indicus*. Body moisture tended to decrease with increasing fat content as has been generally reported in the case of terrestrial animals (Maynard and Loosli, 1969). Ash values appeared to be inversely related to the size of shrimp.

It has been demonstrated that fatty acid patterns of penaeid shrimp reflected those of the dietary lipids (Colvin, 1976; Guary et al., 1976; Kanazawa et al., 1977a, 1979d; Deshimaru et al., 1979; Bottino et al., 1980; Catacutan, 1991). In the present study, similar observations were made for shrimp fed safflower, corn, soybean, linseed or menhaden oil diets which contained high levels of unsaturated fatty acids. For shrimp on stearic acid or coconut oil diets which are high in saturated fatty acids, the levels of these acids were considerably lower than those of the initial and menhaden oil fed shrimp, but were comparable to those of shrimp fed the other diets. However, shrimp fed stearic and coconut oil diets contained high amounts of 16:1*n*-7 and 18:1*n*-9. The levels of these fatty acids were lower for shrimp fed diets containing *n*-6 or *n*-3 fatty acids. The accumulation of these monoenes in *Penaeus vannamei* fed diets deficient in *n*-6 or *n*-3 fatty acids could be an indication of essential fatty acid deficiency. It has been

reported that polyunsaturated fatty acids of the *n*-6 and *n*-3 families inhibit delta 9 desaturase activities in rats. In finfish such as common carp (Takeuchi and Watanabe, 1977), channel catfish (Stickney and Andrews, 1972; Satoh et al., 1989) and milkfish (Borlongan, 1992), high levels of 20:3*n*-9 were considered characteristics of an essential fatty acid deficiency. The difference in the ability of these animals to chain elongate and desaturate fatty acids (Kanazawa et al., 1979b) may be responsible for this discrepancy. Kanazawa et al. (1979d) reported that the tissue lipids of shrimp generally contained very low amounts of 20:3*n*-9 and suggested that other fatty acids should be used as indices to assess the essential fatty acid deficiency. The absence of 20:3*n*-9, and lower concentrations of 20:4*n*-6, 20:5*n*-3 and 22:6*n*-3 in shrimp fed dietary lipid other than menhaden oil as compared with those of the initial shrimp could be attributed to the inability of *Penaeus vannamei* to chain elongate and desaturate 18:1*n*-9, 18:2*n*-6 and 18:3*n*-3 to longer chain HUFA as has been demonstrated in *Penaeus japonicus* (Kanazawa and Teshima, 1977), and *Penaeus monodon* and *Penaeus merguiensis* (Kanazawa et al., 1979c).

Results of this study indicate that menhaden oil rich in*n*-3 HUFA (20:5*n*-3 and 22:6*n*-3) was better utilized by *Penaeus vannamei* than other lipid sources evaluated. Among plant oils, oil rich in 18:3*n*-3 had higher nutritional values than those high in 18:2*n*-6. Thus, both *n*-6 and *n*-3 fatty acids appeared to be dietary essential for *Penaeus vannamei*, although *n*-3 HUFA were required for maximum growth, feed efficiency and survival. Fatty acid patterns of shrimp reflected those of dietary lipids which contained unsaturated fatty acids. Shrimp fed dietary lipid deficient in linoleic and linolenic series of fatty acid accumulated high levels of 16:1*n*-7 and 18:1*n*-9 which may be an indication of EFA deficiency. *Penaeus vannamei* also appeared to lack the ability to bioconvert fatty acids to polyenoic forms of longer chain length. However, more studies are needed to elucidate the essential fatty acid requirements and metabolism of this species.

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